

ANALYSIS OF THE CHARACTERISTICS OF A
PANEL HEATING SYSTEM IN A PUBLIC LIBRARY

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Joseph Wendell Endsley

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PANEL HEATING SYSTEM IN A PUBLIC LIBRARY

4/2
Crawford

Approved:

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Introduction

Data were taken concerning the heating characteristics of the East Atlanta Branch Library, a building heated by means of a panel heating system. For comparative purposes, data were also taken in two other public buildings of similar construction having conventional type heating systems. Of these, the Uncle Remus Branch Library had a fan and furnace heating system, and the Peachtree Branch Library used a fan system for heating.

The object of the test was to determine as nearly as possible the heating characteristics of the panel heating system as compared with the other two types of systems insofar as comfort and economy were concerned.

General Description of Buildings and Heating Systems

The East Atlanta Branch Library is entirely of masonry construction, having outside walls of brick veneer and eight inch load-bearing tile. The walls are plastered everywhere except behind the bookcases, where

plywood is used for backing. The ceiling is covered with accoustical plaster and is insulated with four inches of rock wool. The heat transmission coefficient of walls, ceiling, and floors is respectively 0.25, 0.06, and 0.10 Btu per sq. ft. per °F.¹ There are 25,380 cubic feet of heated space. The boiler that is installed is an American-Standard, 4-GA-11, Empire Boiler. This is a cast iron automatic gas fired boiler for hot water systems, rated by the American Gas Association for an output of 210,000 Btu per hour. The controls include both an inside thermostat and an outside weather bulb. Figure 1 shows a schematic diagram of the boiler and controls. Embedded in the four inch concrete floor slab are one and a quarter inch wrought iron pipes approximately 18" on centers through which hot water is circulated for heating. Figure 2 shows a typical section of the pipe coils.

The Uncle Remus Branch Library is also entirely of masonry construction, having a brick cavity wall with no plaster on the outside walls. The ceiling is covered with accoustical plaster with four inches of mineral wool

¹American Society of Heating and Ventilating Engineers, Heating Ventilating Air Conditioning Guide 1949 pp. 117-141

insulation. The volume of heated space is 42,200 cubic feet. Heat transmission coefficients for the wall, ceiling, and floor are respectively 0.30, 0.05, and 0.10 Btu per sq. ft. per hr. per °F. The furnace is a Payne Series 3 "CB" duct furnace with an output rating of 288,000 Btu per hr. The delivered air is discharged through anemostats in the ceiling. The system was designed for 1000 cubic feet of fresh air per minute, but readings at the intake louver indicated that it was actually taking in about 712 cubic feet per minute. Schematic diagrams of the heating system and controls are shown in figures 3 and 4 respectively.

The Peachtree Branch Library is built with thirteen inch brick walls, plastered on the inside. Like the other two libraries, it has accoustical plaster on the ceiling and four inches of mineral wool insulation. There are 31,600 cubic feet of heated space. Heat transmission coefficients for the wall, ceiling, and floor are respectively 0.34, 0.05, and 0.675 Btu per sq. ft. per hr. per °F. The boiler is an American Standard 4-G-6 cast iron steam boiler. It is rated by the American Gas Association for an out put of 480,000 Btu per hour. The steam coil

in the duct is controlled by a Minneapolis Honeywell modulating steam valve. The system was designed for 850 cubic feet of outside air per minute, but tests indicate that it was actually getting about 1332 cubic feet per minute. Figures 5 and 6 respectively show schematic diagrams of the heating system and controls.

Method of Obtaining Data

For obtaining data for the test, the following equipment was used: sixty immersion type thermometers, one sling psychrometer, one surface pyrometer, one velometer, two twenty-four hour recording thermometers, one seven day recording thermometer, and one stop watch. In addition to these, at each building the gas and electric meters were read. All thermometers were calibrated for the range in which they were used by a thermometer which had been calibrated by the Bureau of Standards in Washington.

For obtaining data on the inside dry bulb temperature distribution, horizontally and vertically, thermometers were suspended vertically from the floor to the ceiling every two feet. This was done in at least five typical locations in each building. One recording thermometer

was placed in a typical location in each building, another was kept in a shaded spot outside. Surface temperatures were taken with a surface pyrometer. A sling psychrometer was used for taking the wet and dry bulb temperatures for the determination of the relative humidity. For computing the amount of fresh air taken in by the warm air systems, the outside louver was traversed with a velometer. Readings were taken on the gas and electric meters once daily or as was necessary. In taking the firing rate, a stop watch was used to observe the time required for a number of revolutions of the five cubic foot hand on the gas meter.

In the East Atlanta Branch Library, the heating panel was supplied by four main piping sections. In the return lines to these sections, thermometer wells had been installed. Thermometers were inserted in these wells for obtaining the temperature of the returning water. By measuring the temperature of pipe surface at a point where the water temperature could be obtained from the thermometer in the well, it was observed that within the range of temperatures encountered, there was no appreciable temperature drop through the wall of the pipe. Therefore, since there were no thermometer wells in the pipes going to the panels, the water temperature could be read directly from

the surface temperature reading on the outside of the pipe. For observing the edge effect of the heating panel, temperatures were read from the surface pyrometer vertically up the outside wall surface, starting on a level with the heating panel, until no change of temperature was recorded.

Station meteorological summaries were obtained from the U.S. Department of Commerce, Weather Bureau for the months in which the test was performed. These reports were valuable in providing information on the number of degree days, wind velocity and direction, and the amount of sunshine for each day.

Discussion

Temperature Control

A chart obtained by the recording thermometer at the East Atlanta Branch Library is shown in figure 7. It can be seen that during unoccupied periods the design temperature of 68°F was maintained fairly close. However, about 10:00 A.M. each weekday a sharp temperature rise is recorded. Then at 2:00 P.M. another sharp increase in temperature took place. A check on the lighting revealed that there were twenty-two 500 watt bulbs providing the lights for the main part of the library. The heat from these lights, if

they were all turned on, was 37,000 Btu per hour.

Consequently, when the janitor turned on about half of the lights in the morning, there was a sharp increase in temperature. Then, when the remaining lights were turned on in the afternoon, there was a still further increase in temperature. Even though the boiler discontinued to supply additional warm water to the panel, there was so much heat stored in the panel that a drastic temperature rise was inevitable.

The effect of the lights very definitely shows the problem of control that arises when a sudden temperature change is encountered with a panel heating system. If the inside dry bulb temperature without lights had been lowered, it would have been too cold when the occupants arrived in the morning. The thermal capacity of the floor slab was 300,000 Btu per °F. Consequently, a considerable amount of time was required for even one or two degrees drop in the temperature of the entire slab, when it is considered that under design conditions the heat loss of the entire building was 77,500 Btu per hour. Outside temperature changes did not appreciably affect the operation of the system because the outside weather bulb anticipated the changes by lowering the circulating water temperature, and because

even though the outside experienced a sharp change, it took a considerable length of time before the change could be transmitted through the walls of the building.

Figure 8 shows a recording thermometer chart taken in the Uncle Remus Branch Library. As can be seen from the chart, the heating system cycled off for approximately nine hours every night beginning at 9:00 P.M. To determine the saving effected by the off cycle period, a 24 hour period was selected for which the temperature remained nearly constant, varying no more than four degrees. By summing up on the temperature chart the times during which the temperature was increasing, the total time that the furnace was running could be computed. When this was multiplied by the firing rate of the furnace, the total cubic feet of gas used over any period could be computed. Values computed by this method checked very closely with those read from the gas meter. Since a period of constant outside temperature was selected, the rate of gas usage would remain constant and consequently the amount of gas that would have been required during the off cycle period could be computed. Comparing the gas saving with the amount that would have been used without cycling off, it was found that approximately 15% was saved. For days in which

the temperature fluctuated, there would be an even greater saving, since the coldest part of the day comes during the early hours of the morning when the furnace would cycle off. The effect of the short heating cycles during the day on the feeling of comfort will be described later.

In figure 9 the chart showing the inside dry bulb temperature for the Peachtree Branch Library is shown. It can be seen that the variation was less than plus or minus one degree. This unusually smooth control was obtained with a Minneapolis Honeywell motorized steam valve.

The temperature variation with time of the panel heating system without lighting effect was somewhat similar to that obtained by the fan heating system.

Figure 10 shows the variation of the outside dry bulb temperature for a typical day in which the temperature remained fairly constant, and figure 11 shows a chart for which the temperature varied more widely. It can be seen from both charts that by assuming the average temperatures to be the mean between the maximum and minimum temperatures a value close to the true average will be obtained. Since that is the manner in which degree days are computed, it might be expected that they would be a fair index of the heat loss to be expected.

Temperature Stratification

One of the most favorable characteristics of the panel heating was the very small amount of temperature stratification. With fairly low outside temperatures and without the effect of the lights, there was no temperature stratification observed, excepting for about the first foot above the floor panel. Up to that level there was about a two degree rise in temperature. This temperature difference of the air immediately next to the panel was to be expected, since the circulation of the air would cause the more dense colder air to congregate near the panel until it picked up sufficient heat to cause it to rise again.

When the lights were turned on, the air near the ceiling became several degrees warmer than that below it. This caused a considerable amount of temperature stratification immediately next to the ceiling. However, from the two foot level up to the four foot level, there still was very little stratification. For comfort, it is only necessary to have minimum stratification up to the six foot level, so even with the lighting effect, the amount of stratification observed was not excessive. Figure 12 shows the temperature stratification with and without lighting effect.

The observed amount of temperature stratification also increased as the outside temperature increased. This variation is shown in figure 13. The average temperature stratification over the entire test was 0.367 °F per foot.

In the Uncle Remus Branch Library, the cycling of the furnace greatly affected the temperature stratification, as can be seen from figure 14. As the furnace came on, the temperature of the air near the ceiling rose greatly, and maximum stratification was obtained. After the furnace cycled off, the fan continued to run, recirculating the air which tended to bring all the air to the same temperature. Temperature stratification, therefore, decreased to a minimum value at the point where it was time for the furnace to turn on again, causing the cycle to repeat. Due to the cycling effect, values for the temperature stratification between the four foot level and the six foot level ranged from 0.17 to 2.13 °F per foot. The average value found for the entire test was 0.89, but this figure was not very meaningful, since the values obtained depended upon which point in the cycle they were taken from.

In the Peachtree Branch Library the temperature stratification cycled somewhat, depending upon the temperature of the delivered air. However, the cycling effect

did not seem to be quite as pronounced as it was in the Uncle Remus Branch Library. This was to be expected, since here a modulated heat supply was used instead of full on and full off. The temperature stratification ranged from 0.375 to 1.90 °F per foot, the average value being 1.23 °F per foot. Figure 15 shows a typical temperature stratification curve for this library.

Mean Radiant Temperature

The basis for the computations of the mean radiant temperature was the formula $q_r = e \times 1.73 \times 10^{-7} \times T^4$, where q_r is the total radiation, Btu per (sq ft) (hr), e is the emissivity, and T is the absolute temperature, °F. Figure 16 shows for the library using panel heating the variation of the mean radiant temperature with outside dry bulb temperature. With no lights on, the mean radiant temperature increased as the outside dry bulb temperature increased. At the same time, the inside dry bulb temperature also increased. It is shown in the figure that without lights the mean radiant temperature remained higher than the inside dry bulb temperature until an outside dry bulb temperature of 62°F was reached. With the lights on, the mean radiant temperature was considerably higher. This was largely due

to the much higher ceiling temperatures encountered.

Figure 17 shows a comparison of the values obtained for all three systems with a constant inside dry bulb temperature of 75 °F. With lights on, the panel system had much higher mean radiant temperatures. Comparing the curve for the panel heating system without lights shown in figure 16 with the curves for the other two systems shown in figure 17, it can be seen that even with the lower inside dry bulb temperatures encountered in the panel heated library, the mean radiant temperature of this system was still the highest. Therefore, from this standpoint, better comfort conditions were obtained with inside dry bulb temperatures of from 68 °F to 72 °F with panel heating than were obtained in the other two systems for dry bulb temperatures of 75 °F.

Relative Humidity

In the library with the panel heating, the relative humidity varied from 22% to 59%, depending upon the conditions outside. It was noted that without the lighting effect higher relative humidities were obtained. This was because lower inside dry bulb temperatures were encountered without lights, and for the same amount of moisture content

the relative humidity is higher for lower dry bulb temperatures. The relative humidity found in the other two libraries was not appreciably different from that found in the library with panel heating.

Characteristics of the Floor Panel

Figure 18 shows the temperature variation along the surface of the floor panel. It can be noted that there is a drop in the panel surface temperature above the coil as the circulating water progresses farther away from the supply line. Most of this temperature drop could be eliminated by using a grid system of coils instead of sinuous coils. However, in no case was the temperature difference more than three degrees, and that amount is not excessive.

With the lights on, most of the heat loss of the building was supplied by the lights, and the circulating pump did not move any water through the panel. Under these conditions, the temperature of the water in the return lines from the panel ranged from 76 °F to 79 °F, and the panel temperature dropped to about 76 °F. Without the lights on, all the heat loss from the building was supplied from the panel, and the temperature of the water in the return lines ranged from 78 °F to 86 °F, with the temperature

of the water in the supply line from five to nine degrees warmer than that in the return line. On a typical day with an outside ambient temperature of 36 °F, the following conditions existed: returning water temperature 86 °F; supply water 94 °F; panel surface temperature 80 °F; inside dry bulb temperature 69 °F. It was noted that when the lights were off, most of the heat supplied by the panel was from radiation. On the same day cited above, 63% of the heat supplied by the panel was from radiation and 37% was from convection.

Figure 19 shows the temperature variation near the concrete slab of the exposed surface of the outside wall due to edge effect. With temperatures ranging around 40 °F the local temperature around the slab differed with that of the rest of the wall by about four or five degrees. The width of this warm band was about one foot. Using the equation given by McAdams for convection of vertical plates, $h = .27 \times (\text{temperature difference})^{.25}$ and the equation cited previously for the radiation loss, it was computed that the increase in the wall loss due to edge effect was 3.67%. Then the wall loss was only 21.8% of the total heat loss for the entire building, making the loss due to edge effect 0.8% of the total heat loss.

Heat Consumption

The variation of heat consumption with degree days per day for the panel heating system is shown in figure 20. It can be seen that the heat supplied from the lights was an appreciable amount of the total heat input even though they were not turned on more than about six to eight hours per day. Figure 21 shows the variation of heat input with degree days for the fan and furnace system. In this figure the relative heat input from normal lighting load can be seen. In the Peachtree Branch Library, flourescent lights were used. Figure 22 shows some reduction in the heat input from the lights due to the use of this kind of lighting.

In figure 23, the total heat input for the three systems is compared. It can be seen that the panel heating system and the fan and furnace heating system required about the same amount of heat per 1000 cubic feet of heated space; the fan heating system requiring about twice as much as these two. The boilers or furnaces used in all three systems were rated by the American Gas Association at 80% efficient and it was found from heat balances that each boiler was performing normally. However, there were several conditions for the fan heating system which were not comparable to the other libraries. This building had a

crawl space under the floor slab causing more heat loss to occur through the floor. The heating system was not cycled off at night as was the case with the fan and furnace system. In addition to this, tests made with a velometer revealed that about 57% excessive ventilation was being introduced. Also velometer tests revealed that the fan and furnace system was actually taking in 29% less air than what it was designed for. Due to the newness of the buildings, these conditions had not been corrected when the test was made. When all these factors are taken into consideration it would be expected that the fan system and the fan and furnace system would perform with equal economy. This would then make the panel heating system the most economical, but it would receive less ventilation than a forced air system. If the ventilation requirements of all three systems were made equal, the panel system would still be as economical as the other two systems. Under normal performance, the inside dry bulb temperature of this type of system can be held several degrees below the temperature that would be required for the conventional types of systems. The lower temperature requirements would offset any increased heat loss through the floor due to the hot cement slab. For the period February 20 through March 8,

the total heat input per degree day per 1000 cubic feet of heated space was as follows: for the panel system, 1.69; for the fan and furnace system, 1.94.

Relative Costs

The cost of the panel heating system was about 10.64 cents per cubic feet of heated space. It was difficult to determine the cost of the other two heating systems alone because they had air conditioning and the heating and cooling systems had to be separated. Making this allowance, the cost of the warm air systems was roughly estimated to be 9.00 cents per cubic feet of heated space, or about 84% of the cost of panel heating.

Conclusions

From the standpoint of comfort, under normal conditions the panel heated system was superior. For best control, fluorescent lighting would be recommended, since it emits the least amount of heat for the same lighting effect. Sudden loads present very difficult problems of control for panel heating. The initial cost of a panel heating system is about 20% higher than that for ordinary warm air systems. In climates such as are found in Atlanta, Georgia where the test was made, the values obtained for relative humidity

are satisfactory. However, in very cold climates or in localities having low humidity, the relative humidity would not be high enough.

It does have many very distinct advantages. The values obtained for temperature stratification and mean radiant temperature are excellent. It had the advantage of being entirely free from drafts, and the warm floors obtained are quite desirable especially in such places as libraries and schools where children are present. Also it is free from any noise which is sometimes experienced in warm air systems. Considering that the fuel consumption is as economical as that found in conventional systems, and that it has so many advantages insofar as comfort is concerned, the slight additional first cost seems to be justified.

BIBLIOGRAPHY

Allen, John R., Walker, James Herbert, and James, John William, Heating and Air Conditioning. New York and London: McGraw-Hill Book Company, Inc., 1946. 667 pp.

Heating Ventilating Air Conditioning Guide. New York: American Society of Heating and Ventilating Engineers, 1949. 992 pp.

Jakob, Max and Hawkins, George A., Elements of Heat Transfer and Insulation. New York: John Wiley & Sons, Inc., 1942. 169 pp.

Jakob, Max, Heat Transfer. New York: John Wiley & Sons, Inc., 1949. 758 pp.

Marks, Lionel S., Mechanical Engineers' Handbook. New York and London: McGraw-Hill Book Company, Inc., 1941. 2274 pp.

McAdams, William H., Heat Transmission. New York and London: McGraw-Hill Book Company, Inc. 1942. 459 pp.

APPENDIX I

Sample Computations, (Panel Heating)

Temperature stratification, °F per foot = (Temperature difference) / (Vertical distance)

$$(75.4 - 74.3) / (4) = 0.275$$

$$\text{Mean radiant temperature} = \left(\frac{q_r}{e \times 1.73 \times 10^{-7}} \right)^{\frac{1}{4}}$$

Where q_r is the total radiation, Btu per (sq ft) (hr)

e is the emissivity = 0.95.²

Using a table³ based on the above equation, the following values were obtained:

	Area	Surface temp.	q_r	$q_r \times \text{Area} \times 10^{-2}$
Outside wall	915	70	129.3	1183
Outside wall	826	73	132.0	1090
Glass	551	62	121.8	671
Partition	480	71	130.1	625
Ceiling	1832	72	131.0	2400
Floor	1832	76	135.5	2480
	<u>6436</u>			<u>8449</u>

Mean $q_r = (\text{Sum of } q_r \times \text{Area}) / (\text{Total Area})$

8449/6436 = 132.5; from the table this corresponds to a mean radiant temperature of 72.2 °F

³ American Society of Heating and Ventilating Engineers, Heating Ventilating Air Conditioning Guide, 1949 p.625

⁴ McAdams, William H., Heat Transmission, New York: McGraw-Hill Book Company, Inc., 1942, table XIII

Thousand Btu per day per 1000 cubic feet heated space = (Thousand Btu per day) / (Thousand cubic feet heated space)

Btu per day = cu ft gas per day x heating value of gas x boiler efficiency + kw hr per day x 3413

$$1210 \times 1026 \times 0.80 + 62.5 \times 3413 = 1,195,000$$

$$1,195/25.38 = 47.2$$

Heat loss through walls etc. = overall heat transfer coefficient x area x temperature difference

$$U = 1/(1/k_1 + 1/k_2 + \dots + 1/c_1 + 1/c_2 + \dots)$$

Where U is the overall heat transfer coefficient, k is the conductivity, and c is the conductance

$$U_{\text{wall}} = 1/(.19 + .43 + .91 + 1.67 + .23 + .53) = 0.252$$

$$\text{Heat loss through wall} = 0.252 \times 1349 \times 40 = 13,600$$

Heat Balance (Panel Heating)

For Period of March 1, 7:00 P.M. to March 2, 7:00

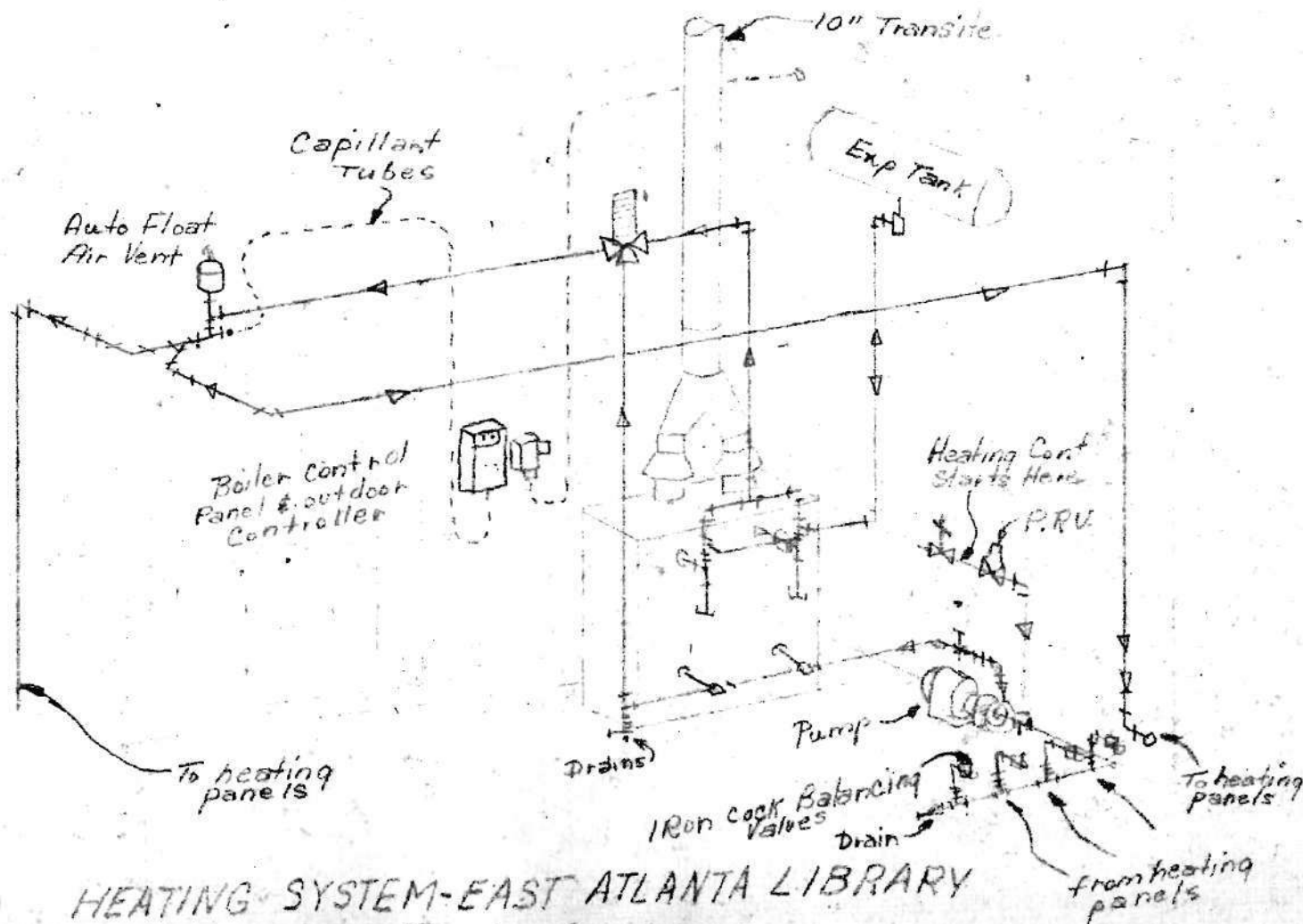
P.M.

Total Btu input	1,231,000
Heat loss from walls, ceiling, glass, and infil.	1,086,500
Heat loss through floor	<u>155,500</u>

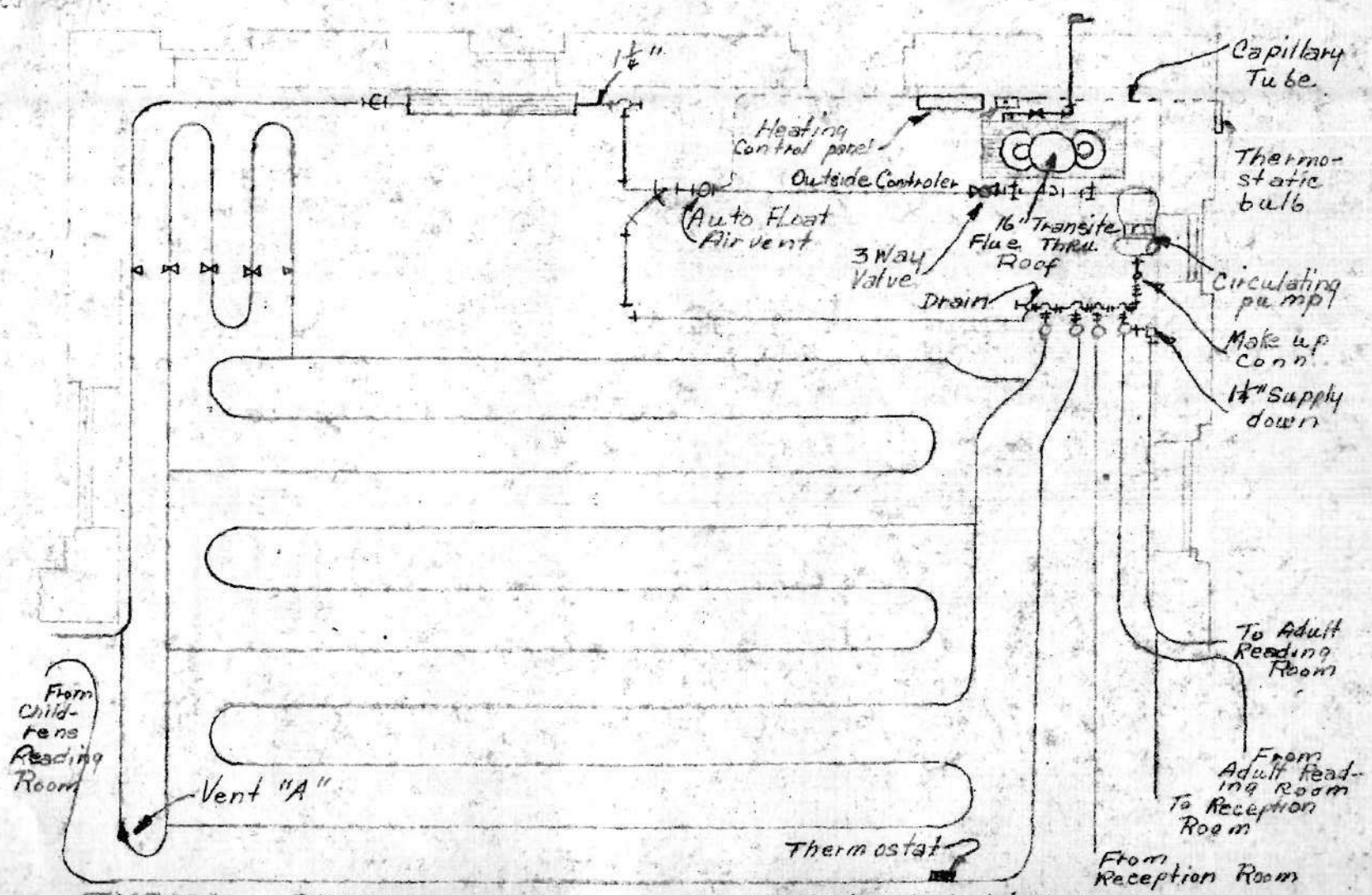
$$\text{Heat loss through floor} = 12.62\%$$

APPENDIX II

Figures

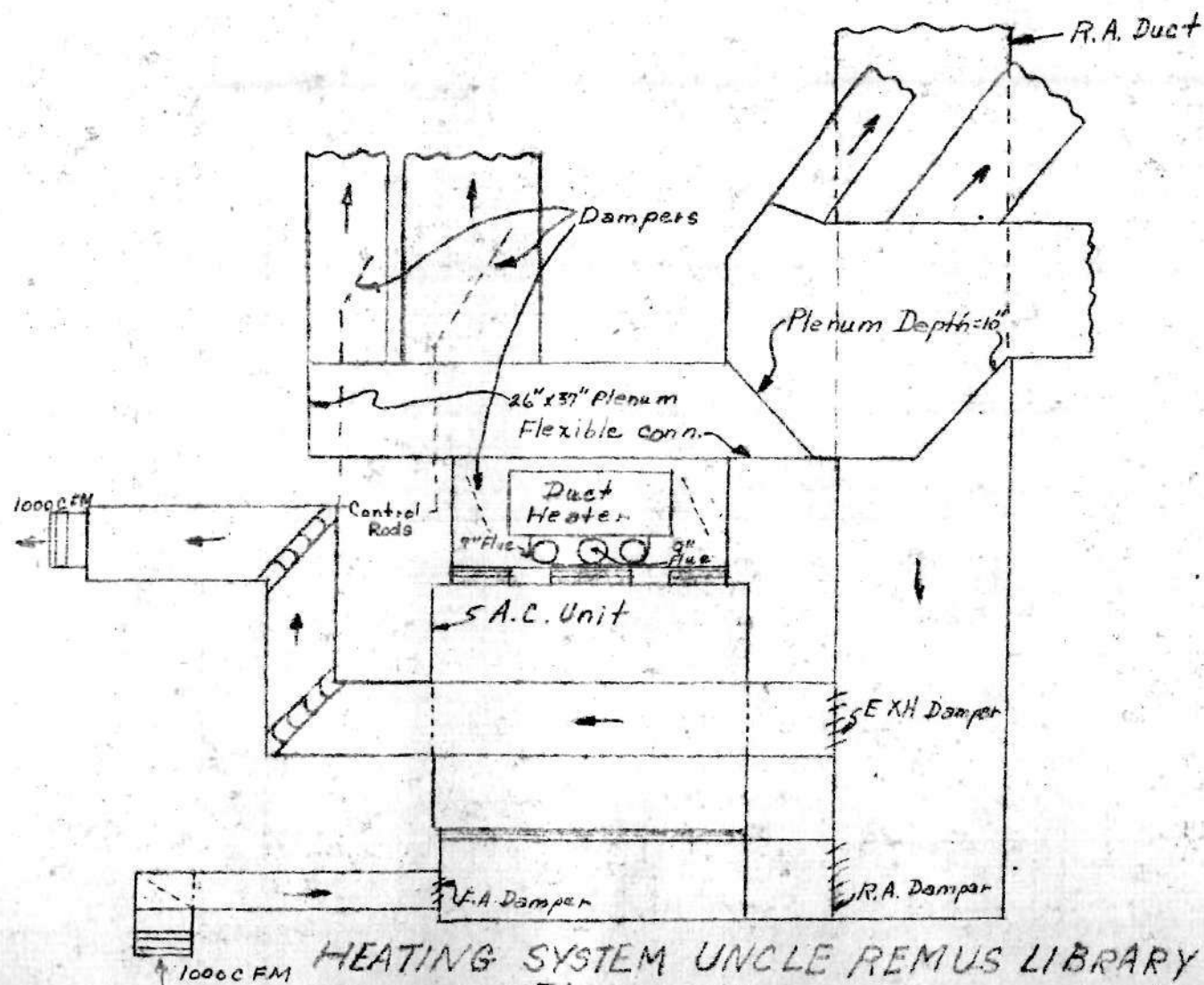


HEATING SYSTEM-EAST ATLANTA LIBRARY
Figure 1

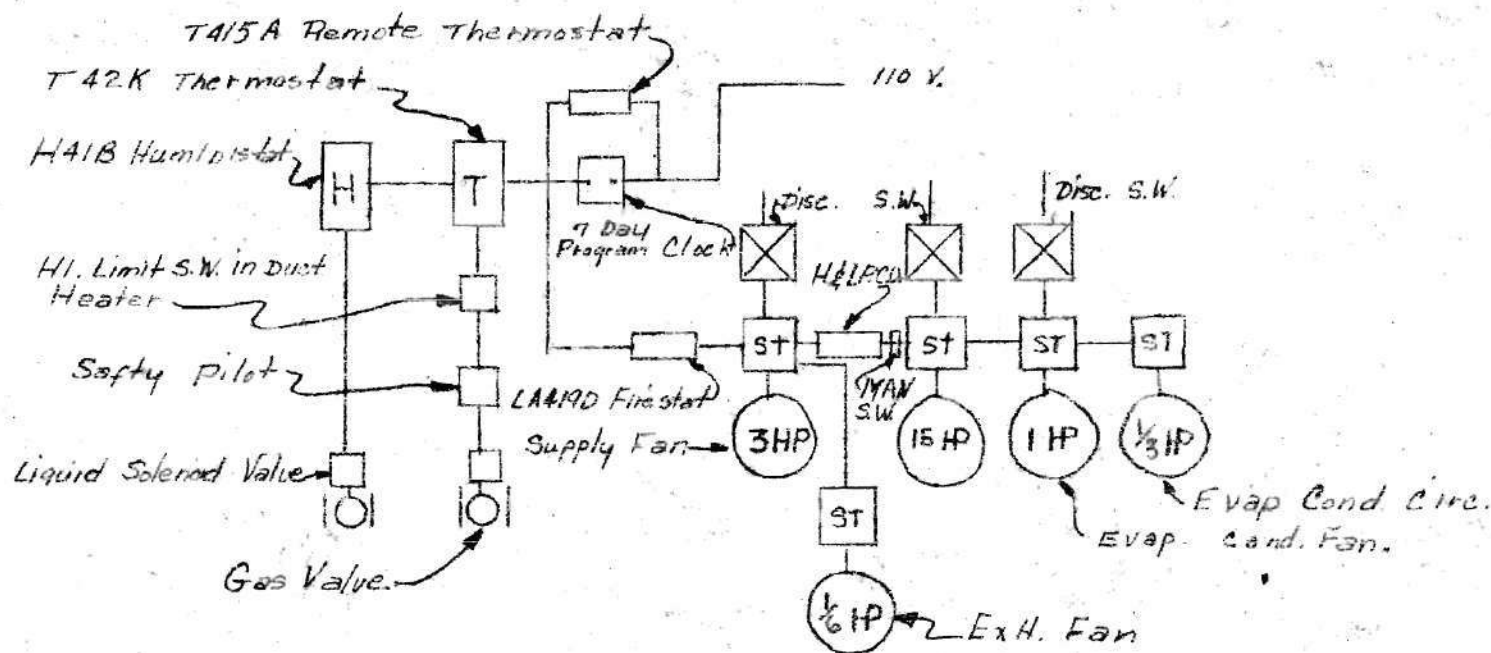


TYPICAL SECTION OF COILS - EAST ATLANTA LIBRARY

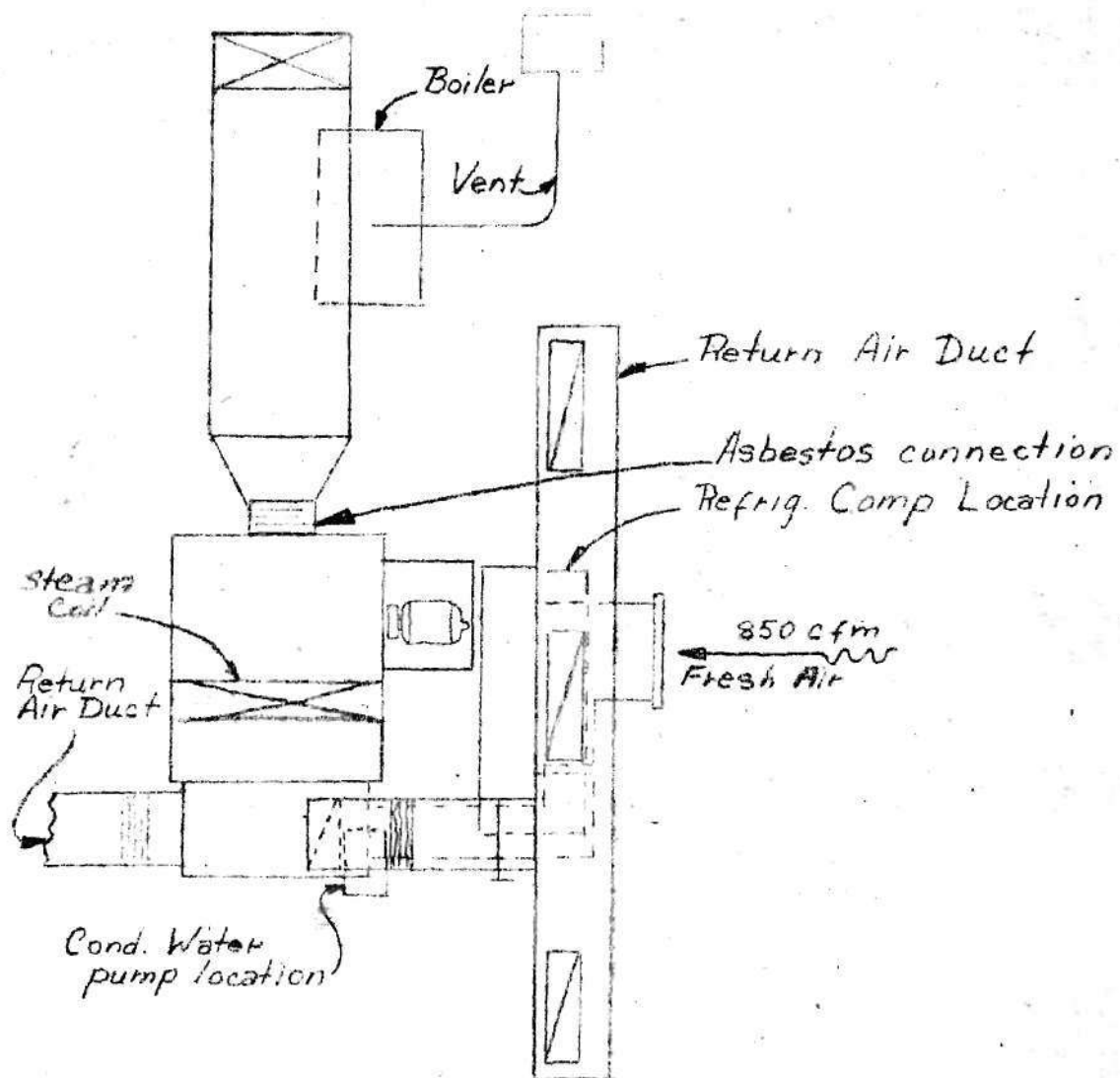
Figure 2



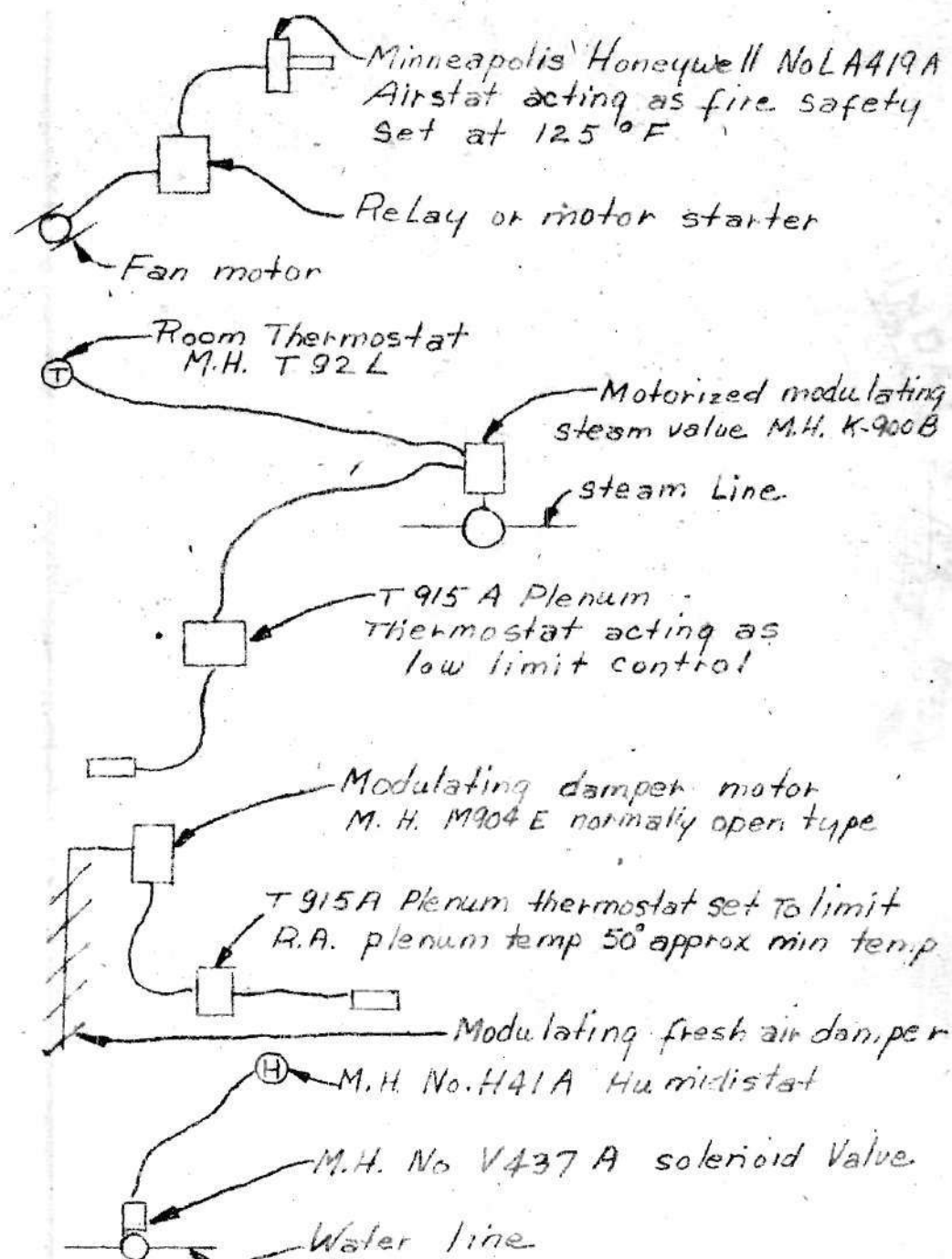
HEATING SYSTEM UNCLE REMUS LIBRARY
Figure 3



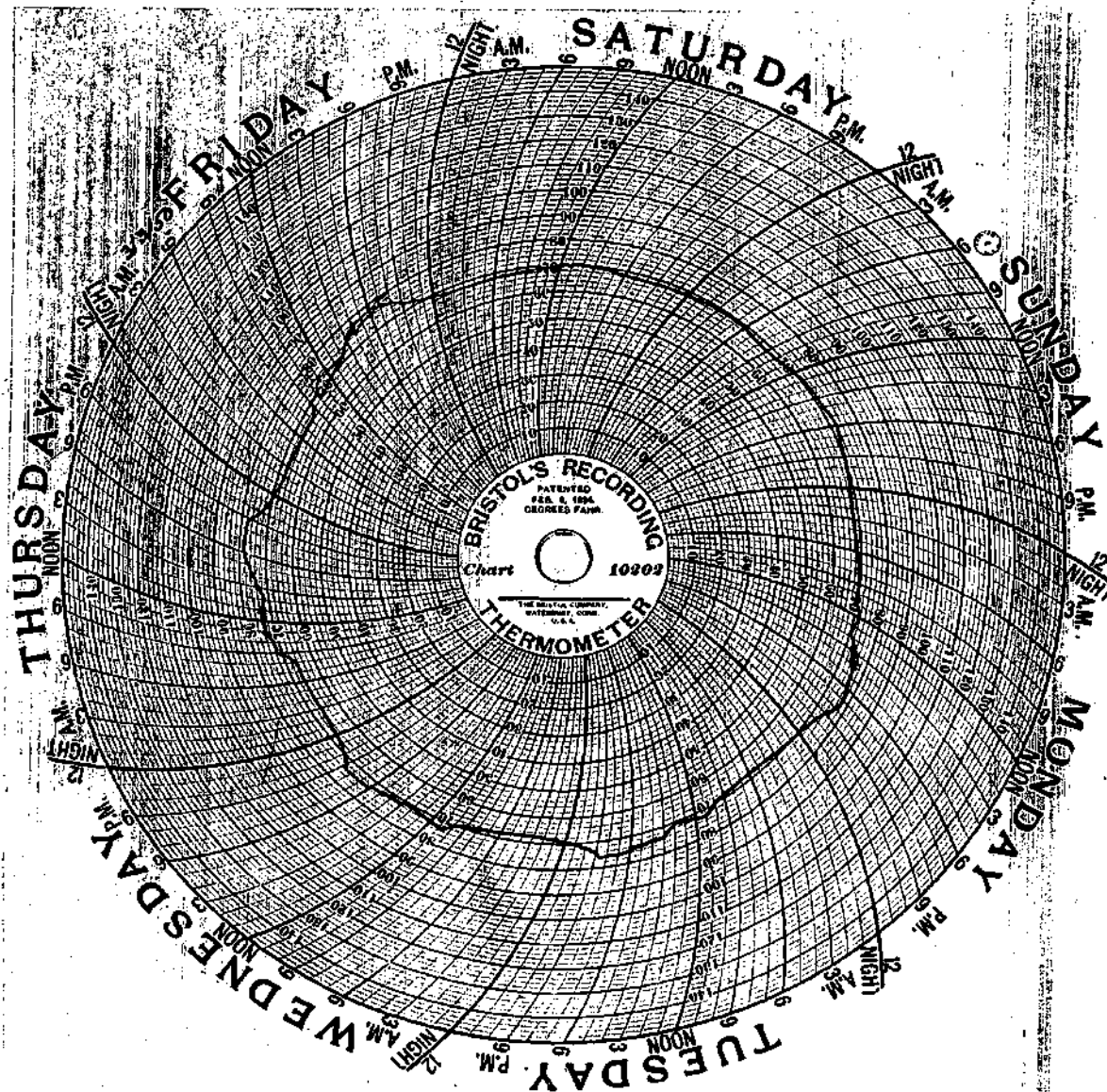
HEATING CONTROLS - UNCLE REMUS LIBRARY
Figure 4



HEATING SYSTEM- PEACHTREE LIBRARY
Figure 5.

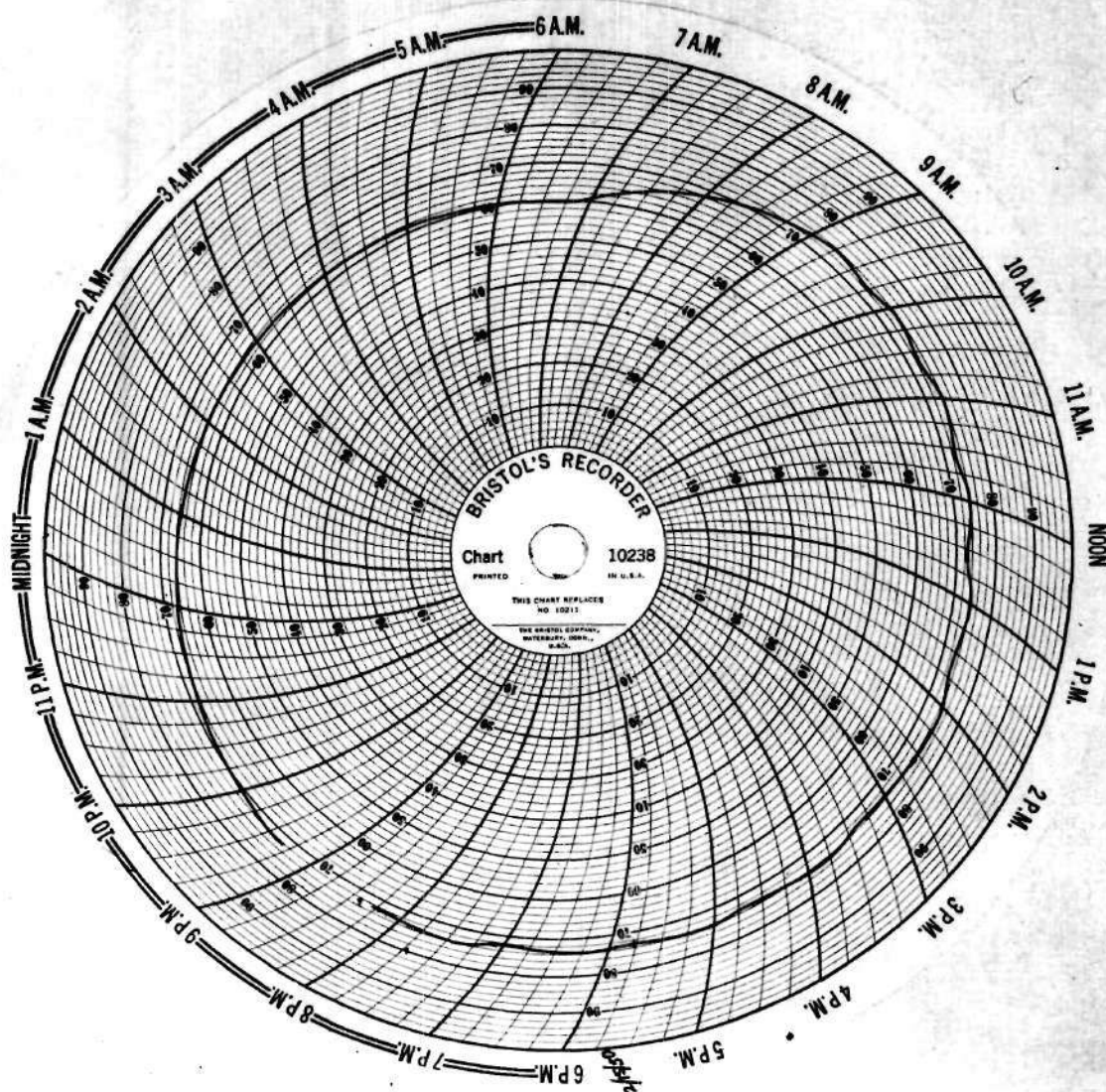


HEATING CONTROLS-PEACHTREE LIBRARY
Figure 6



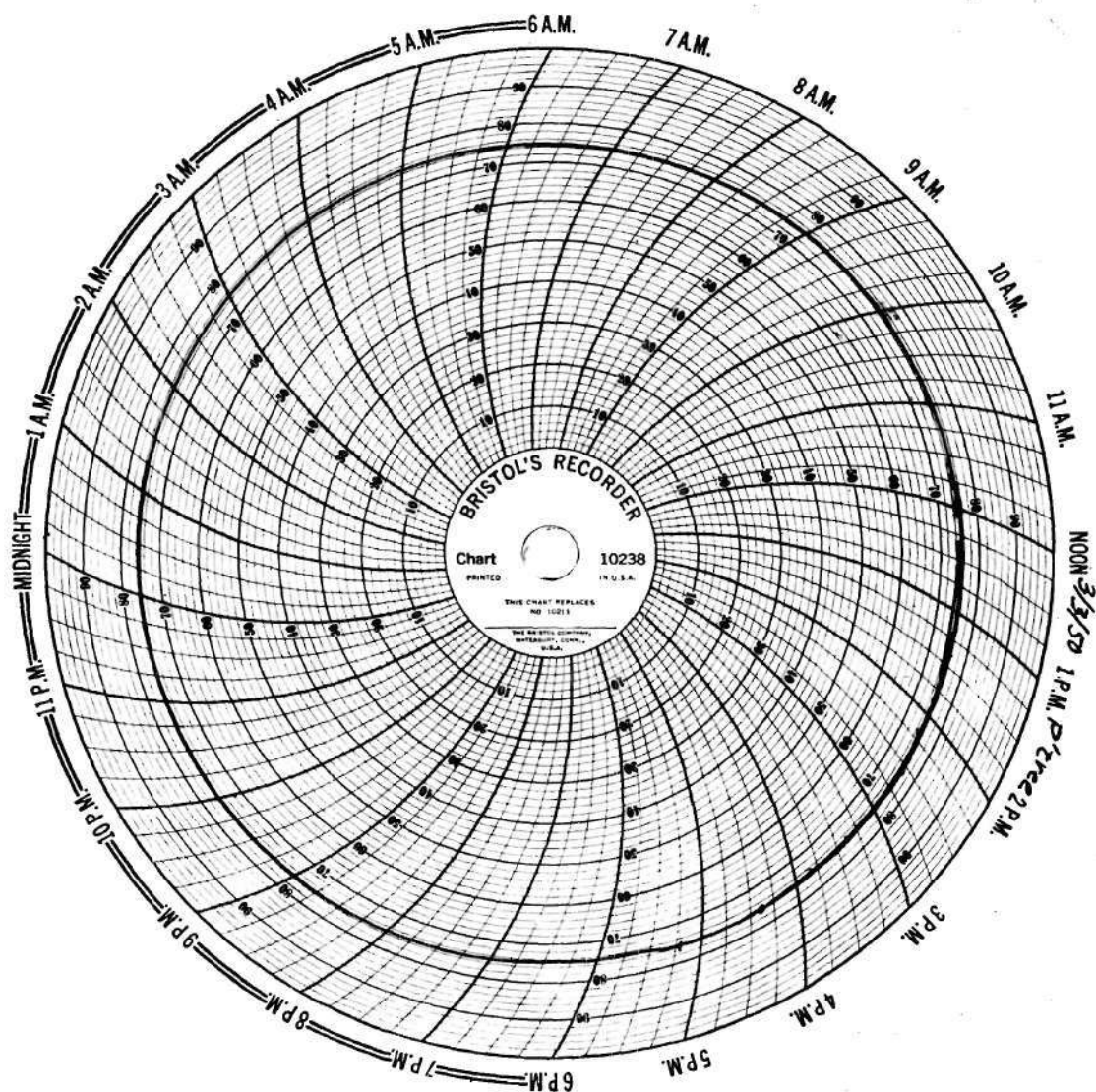
TYPICAL CHART OF INSIDE
 DRY BULB TEMPERATURE
 10:00AM March 3, 1950 To
 9:00PM March 10, 1950
 East Atlanta Branch Library
 Bristol's 7 Day Recording
 Thermometer

Figure 7



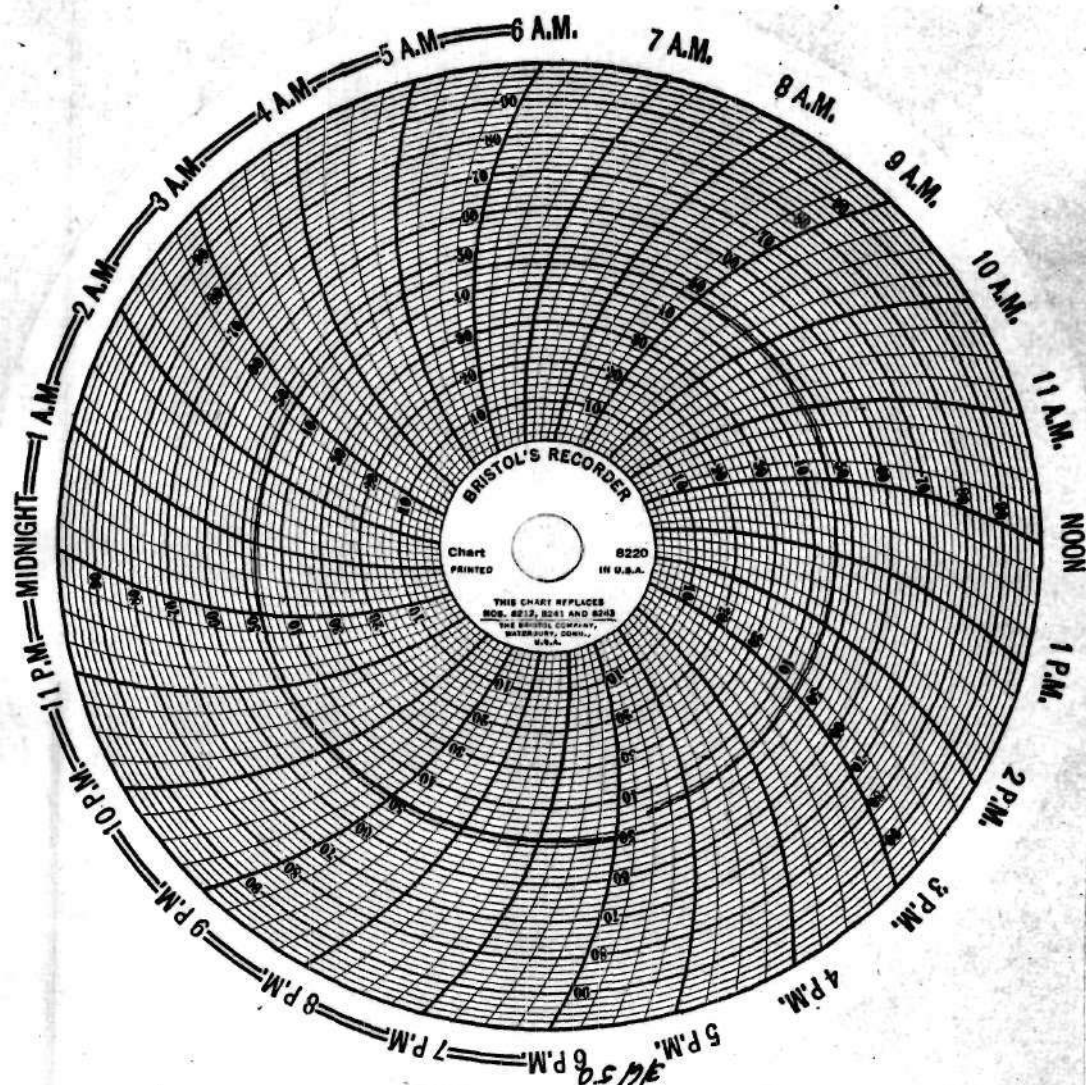
TYPICAL CHART OF INSIDE
 DRY BULB TEMPERATURE
 9:20 P.M. February 15, 1950
 To 8:15 P.M. February 16, 1950
 Uncle Remus Branch Library
 Bristol's 24 Hr. Recording
 Thermometer.

Figure 8



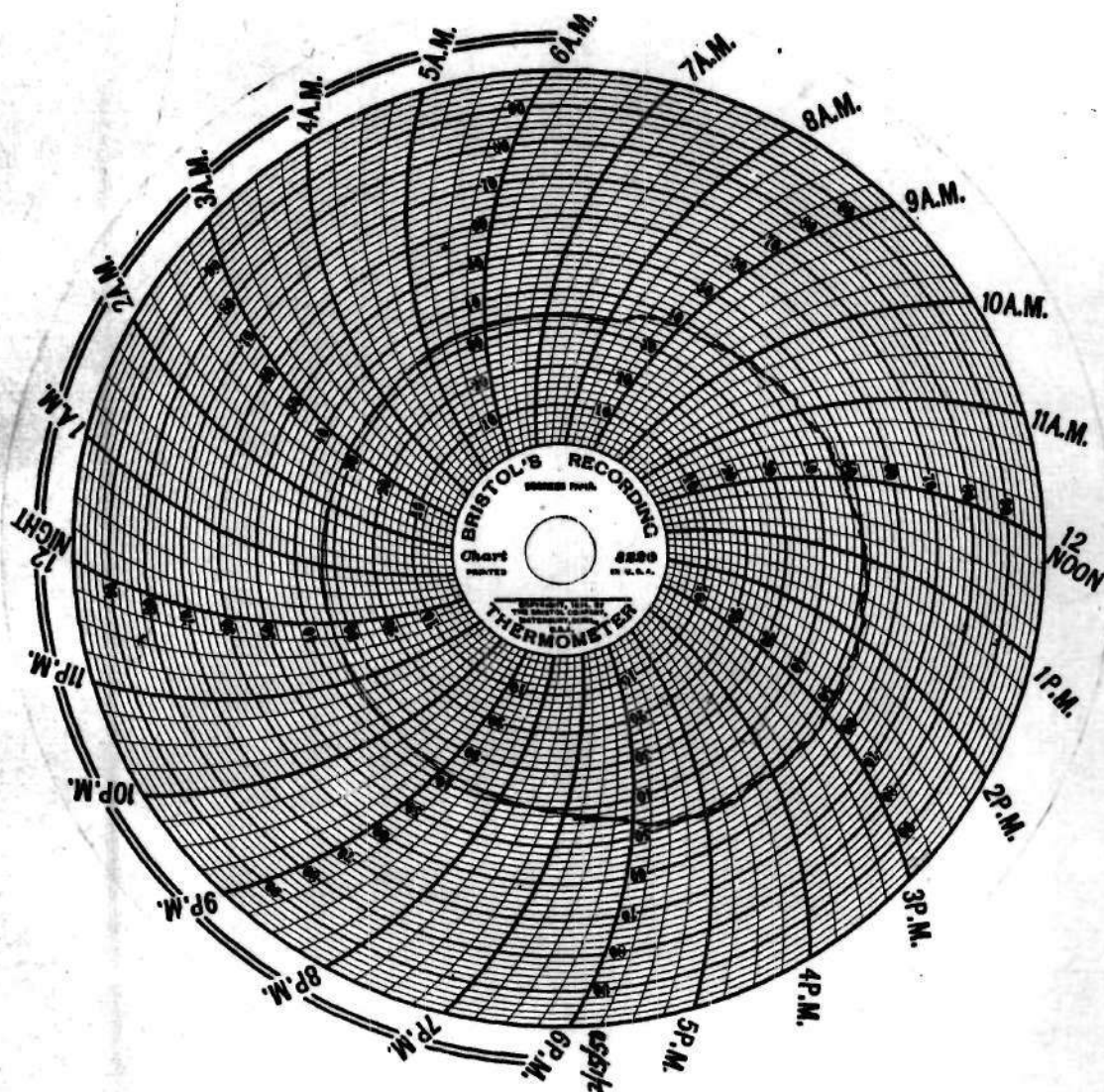
TYPICAL CHART OF INSIDE
 DRY BULB TEMPERATURE
 12:20 P.M. March 3, 1950 TO
 4:00 P.M. March 4, 1950
 Peachtree Branch Library
 Bristol's 24 Hr. Recording
 Thermometer.

Figure 9



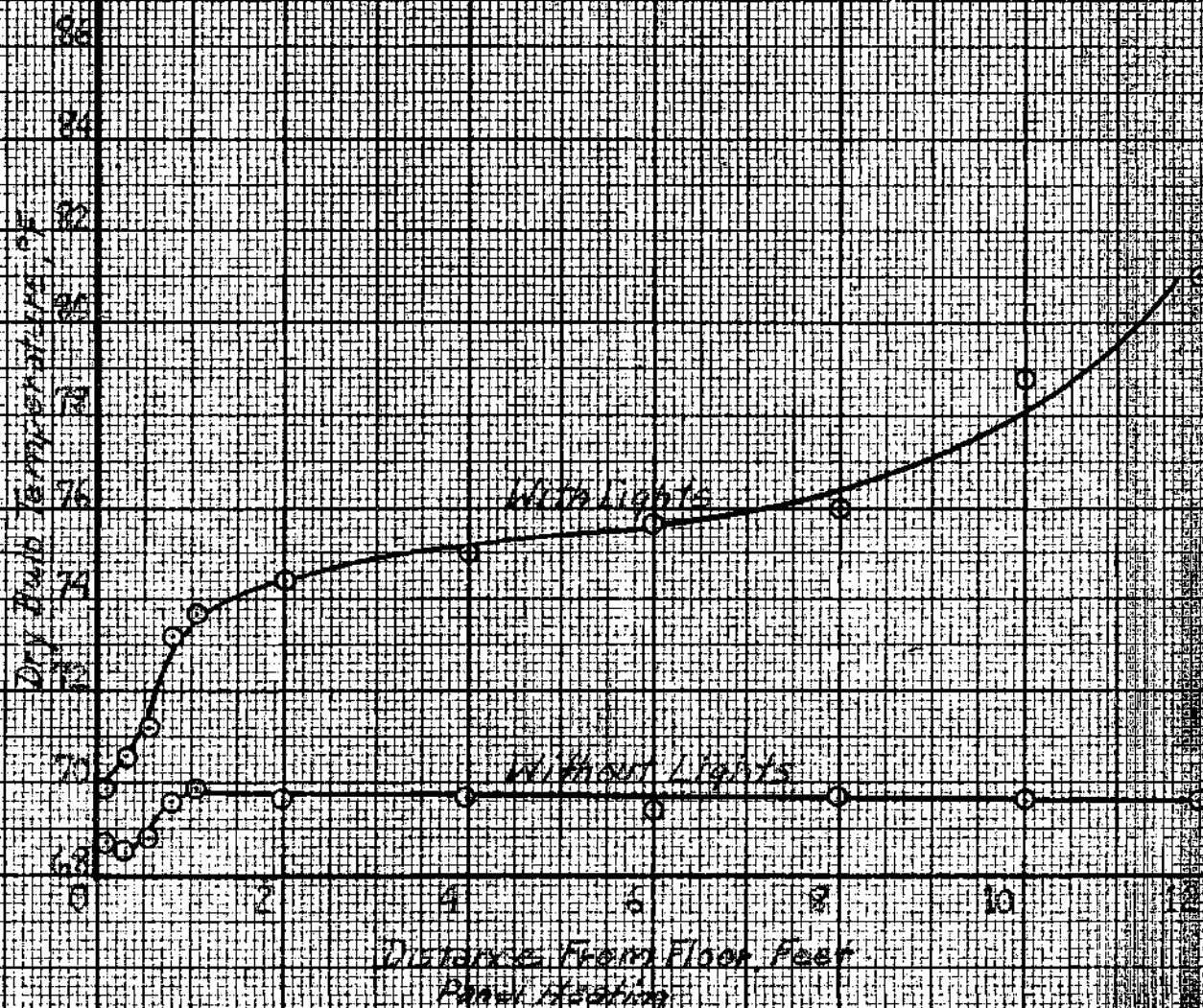
TYPICAL CHART OF
OUTSIDE TEMPERATURE
6:00 PM March 6, 1950
To 5:30 PM March 7, 1950
0 Hrs. 00 Mins. Sunshine
Bristols 24 Hour Recording
Thermometer

Figure 10



TYPICAL CHART OF
OUTSIDE TEMPERATURE
600PM February 15, 1950
To 645PM February 16, 1950
6 Hrs. 38 Min. Sunshine
Bristols 24 Hr. Recording
Thermometer.

Figure 11

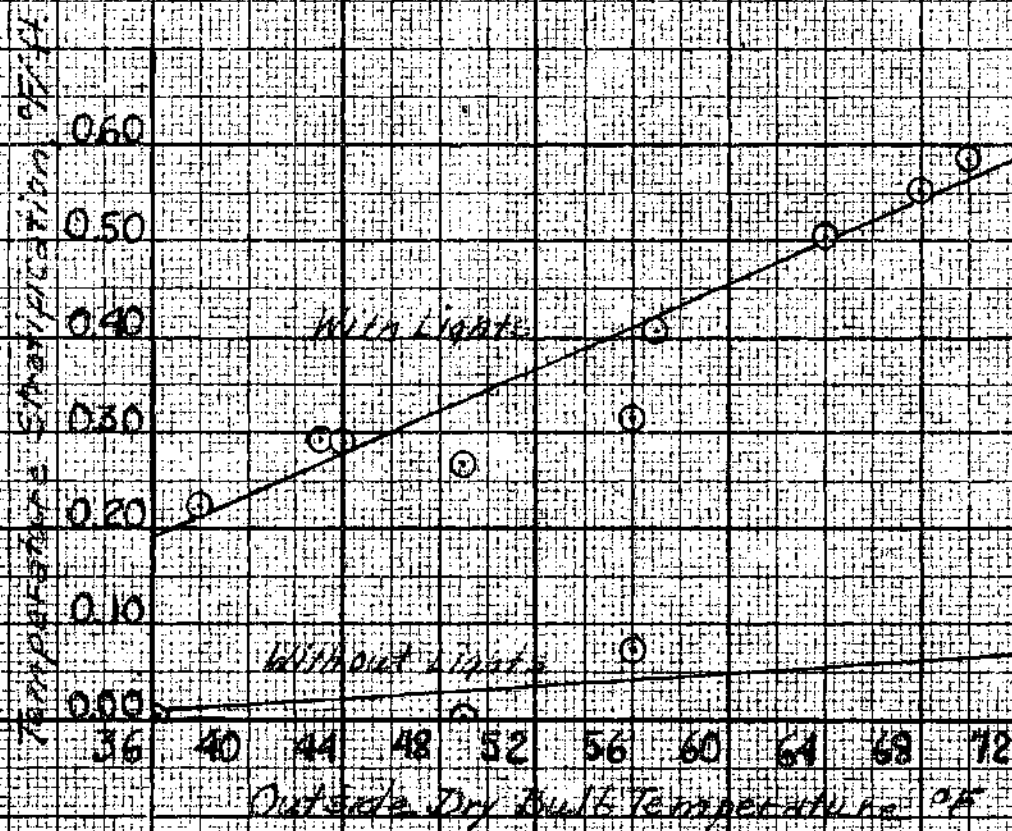


TEMPERATURE STRATIFICATION
CURVE WITH AND WITHOUT
LIGHTING EFFECT

East Atlanta Branch Library
March 3, 1950

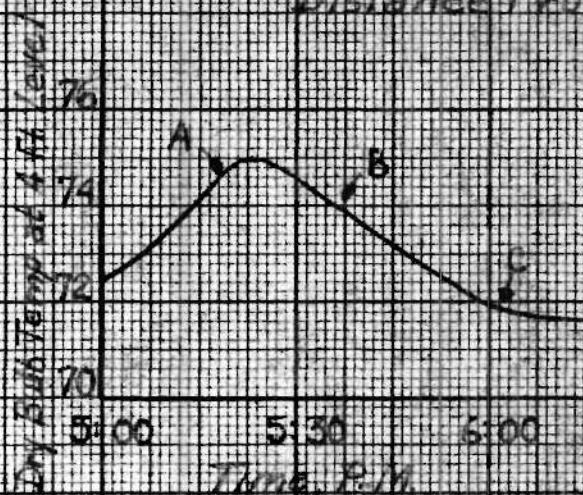
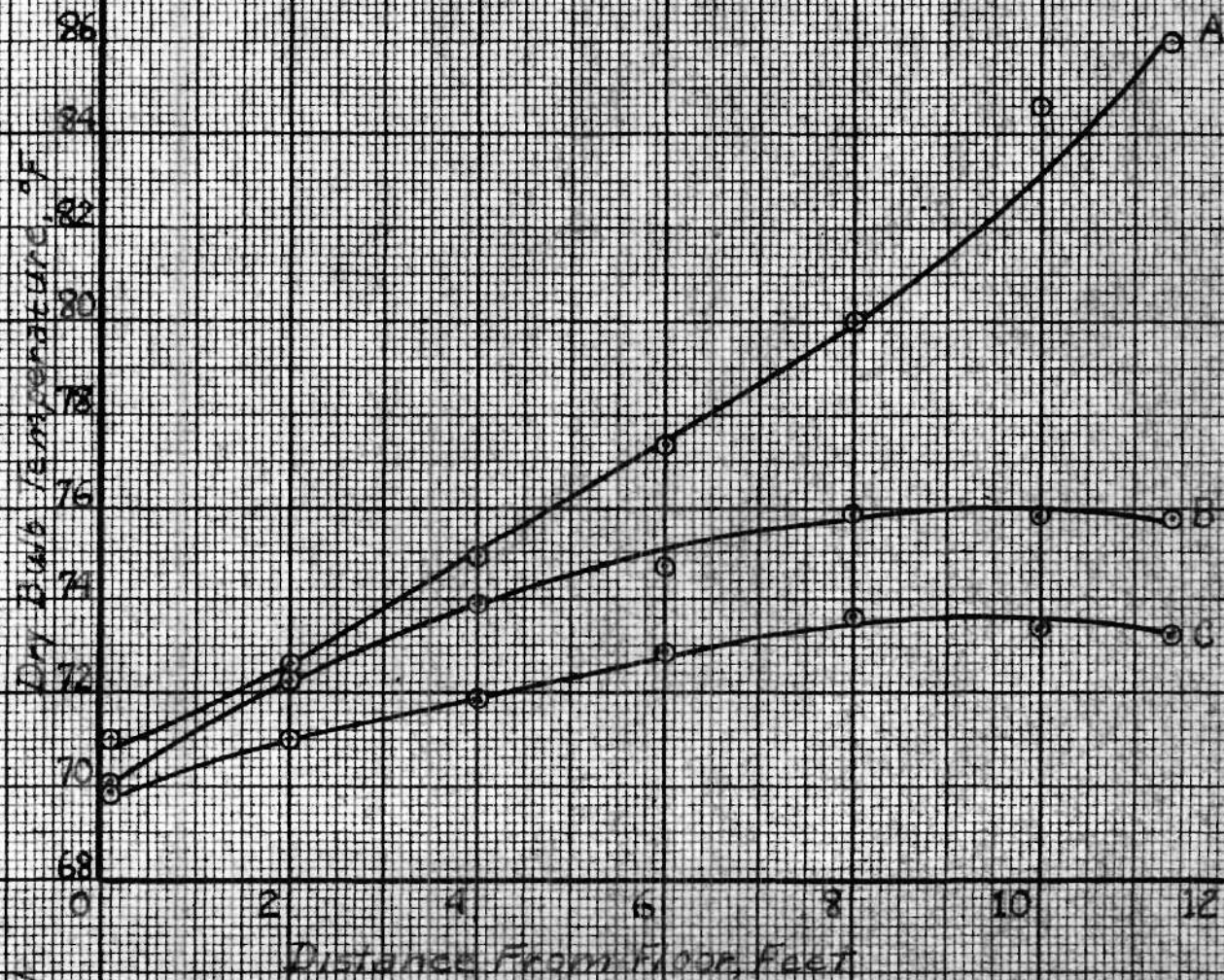
Outside Ambient Temperature 50°F

Figure 12



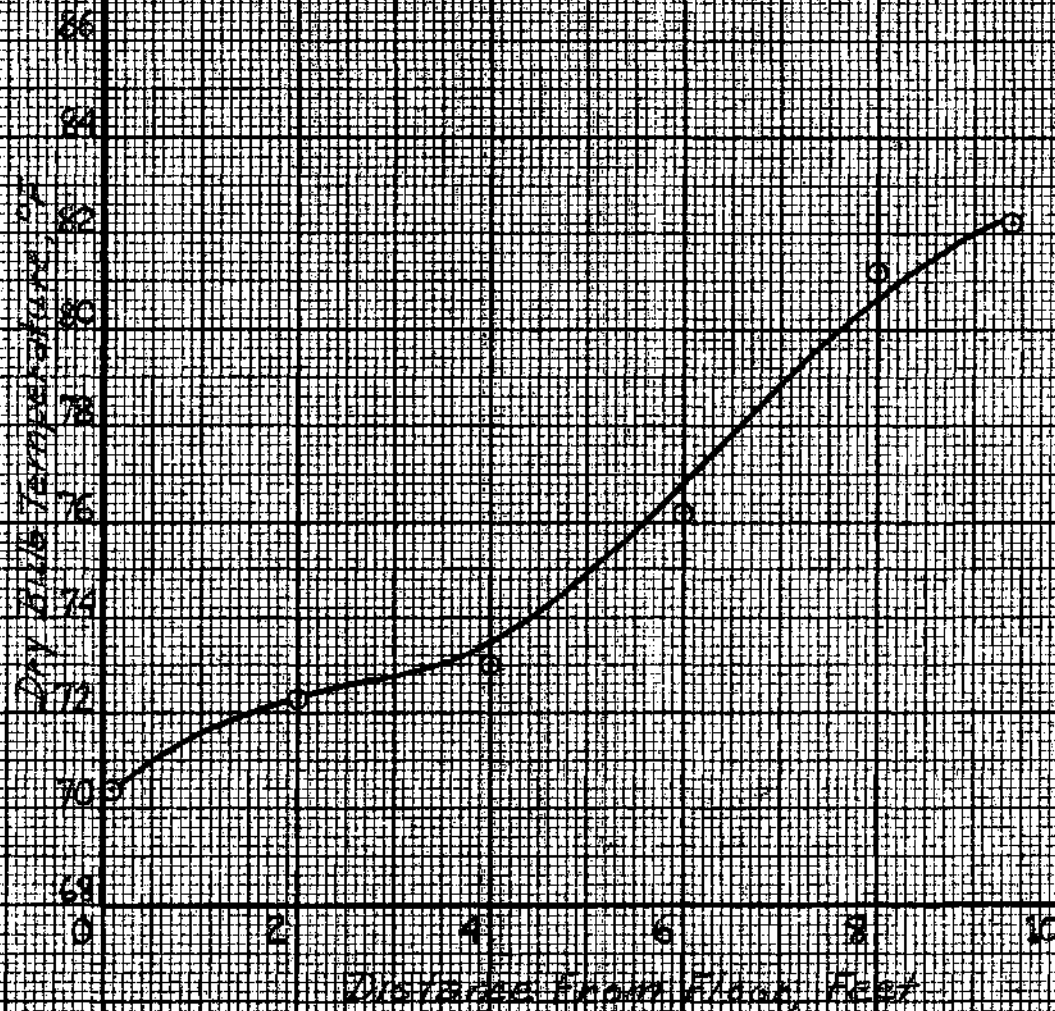
VARIATION OF TEMPERATURE
STRATIFICATION WITH OUT-
SIDE DRY BULB TEMPERATURE
East Atlanta Branch Library
Fan Coil Heating

Figure 13



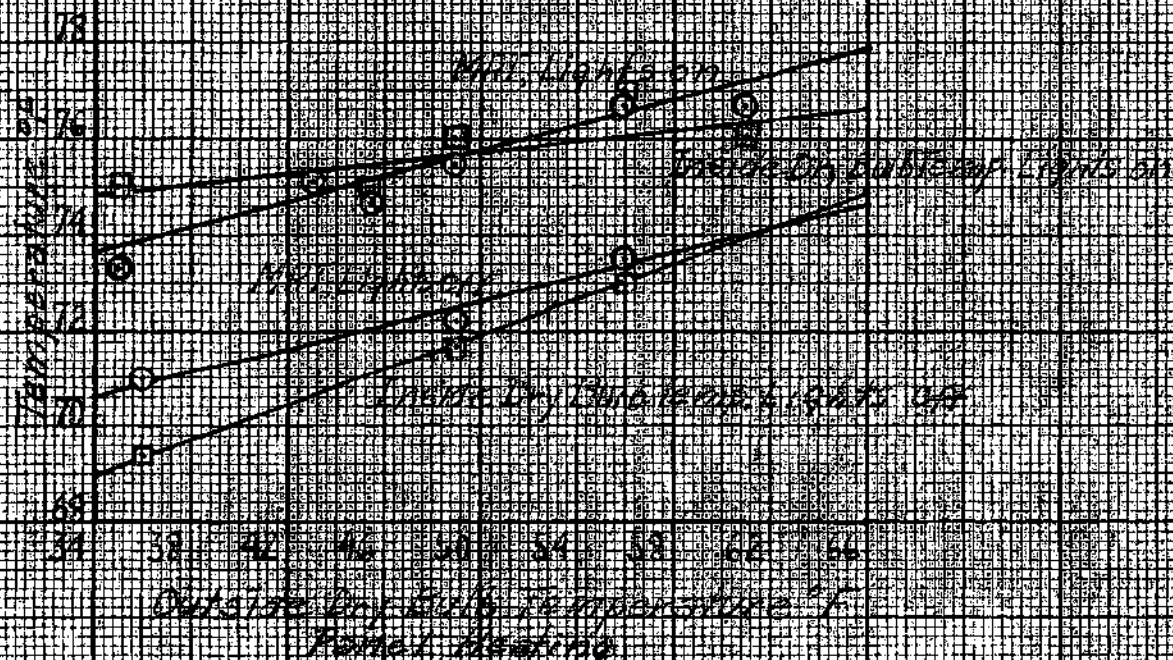
TEMPERATURE STRATIFICATION
WITH CONSTANT FAN OPER-
ATION, FURNACE CYCLING
Uncle Remus Branch Library
February 17, 1950
Outside Ambient Temperature 40°F

Figure 19



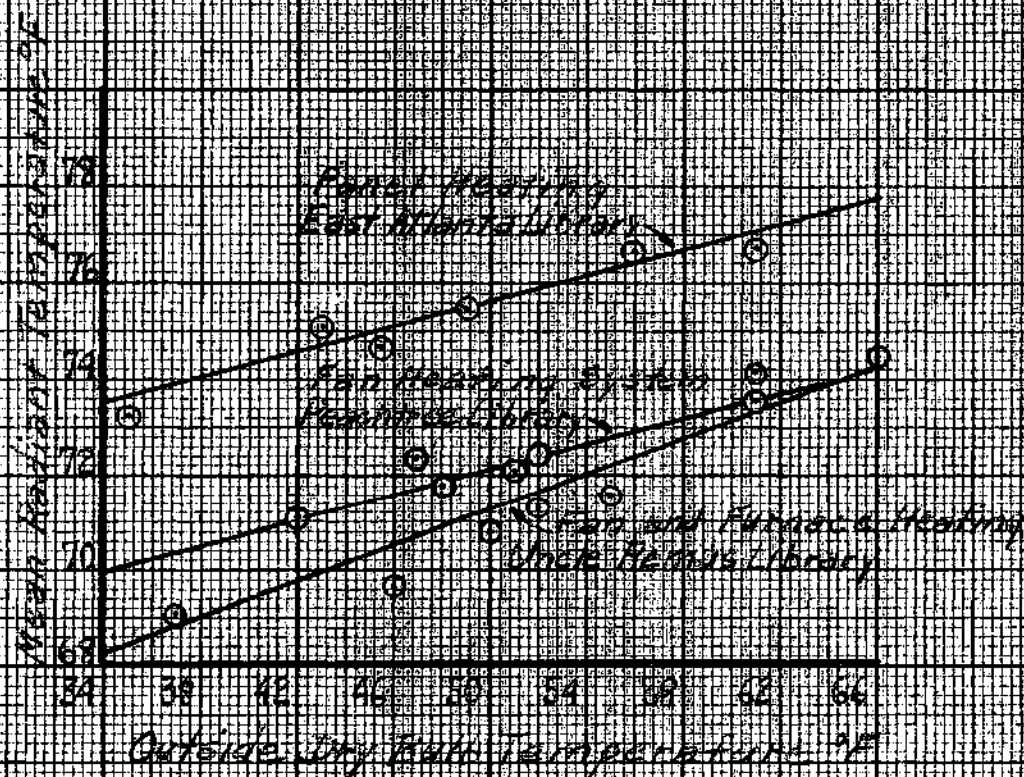
TYPICAL TEMPERATURE
STRATIFICATION CURVE
Peachtree Branch Library
February 23, 1950
Outside Ambient Temperature 41°F
Fan Heating System

FIGURE 15



MEAN RADIANT TEMPERATURE
VARIATION WITH OUTSIDE DRY
BULB TEMPERATURE
FOR PANEL HEATING

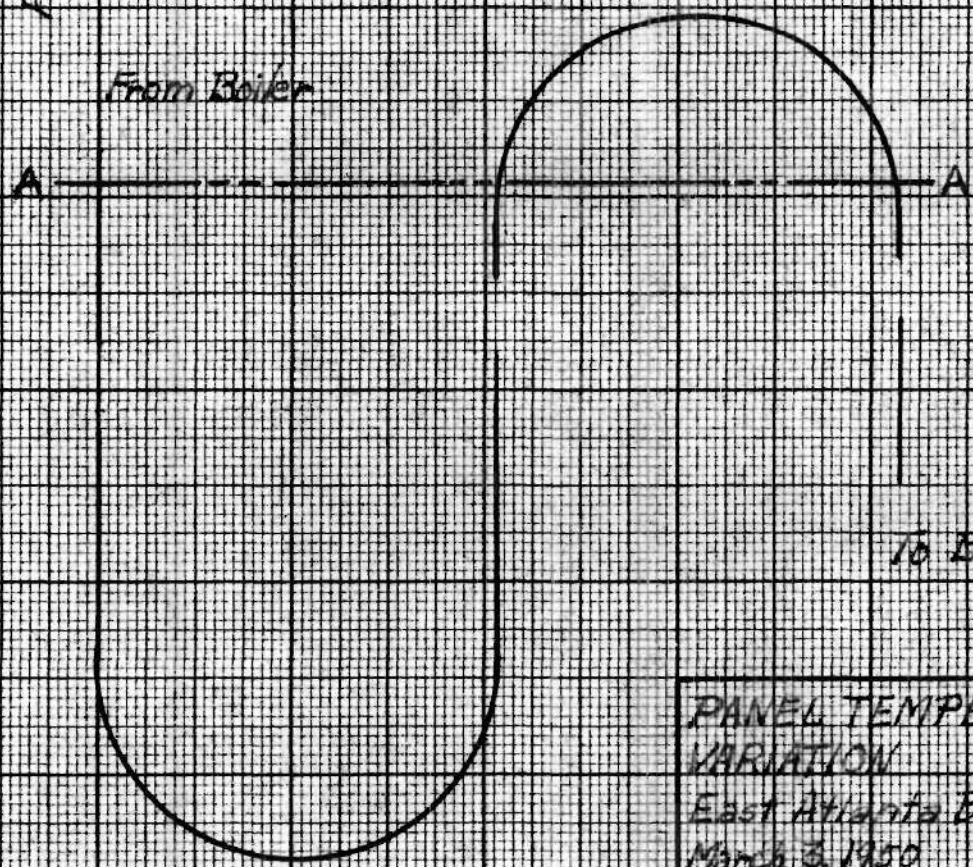
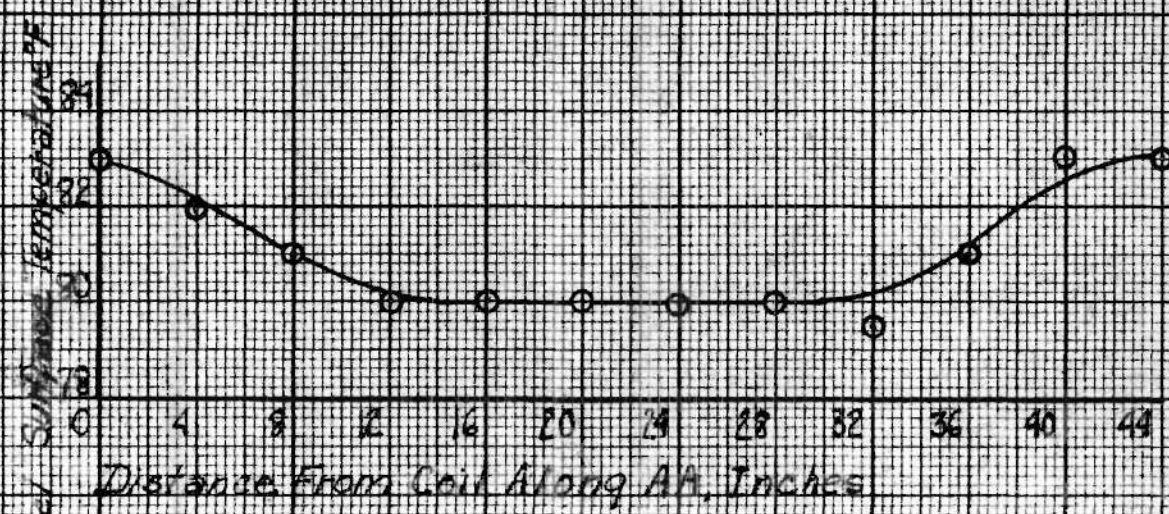
Figure 16



MEAN RADIANT TEMPERATURE
VARIATION WITH OUTSIDE
TEMPERATURE
Inside Dry Bulb Temperature 75°F

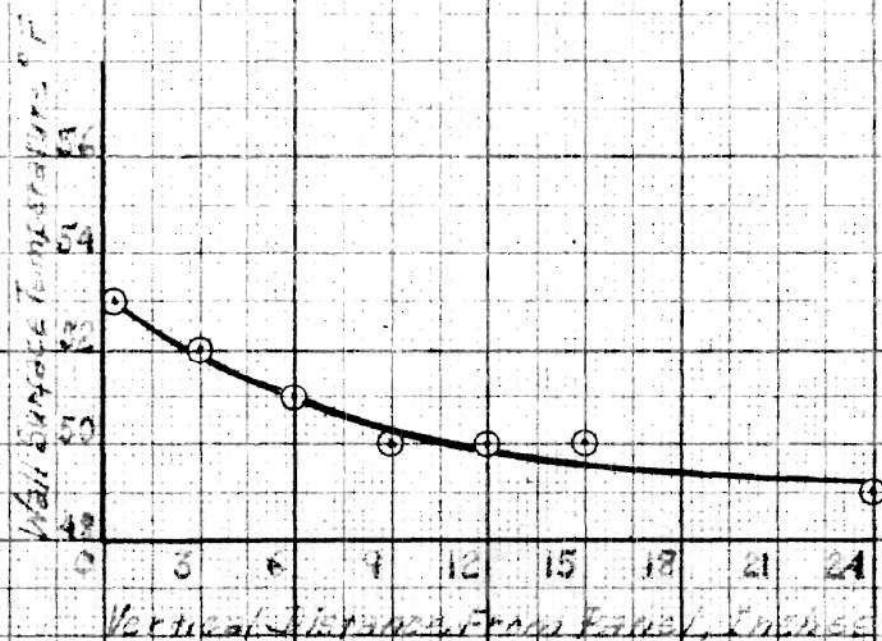
Figure 17

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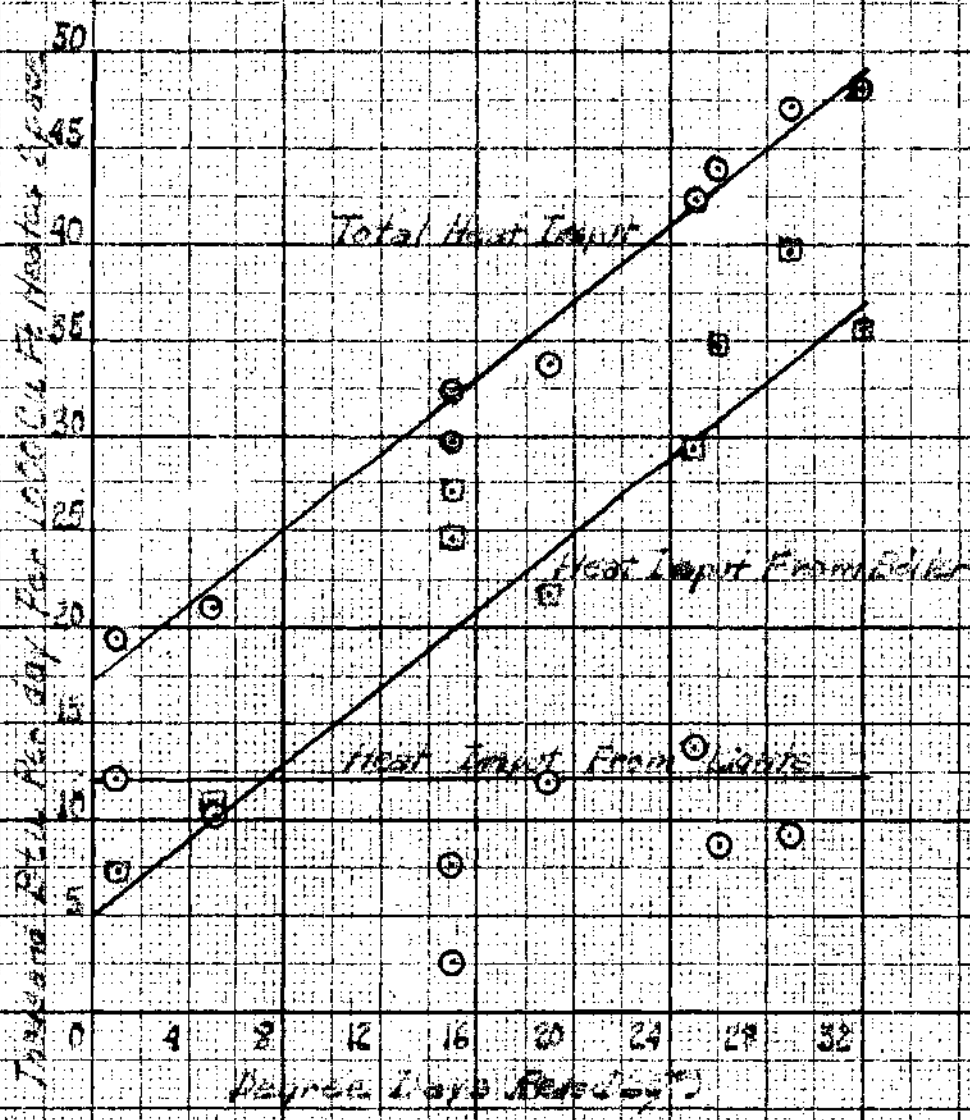
PANEL TEMPERATURE
VARIATION
East Atlanta Branch Library
March 3, 1950
Circulating Water in 19°F
Circulating Water out 85°F
Outside Ambient Temperature 36°F

Figure 18



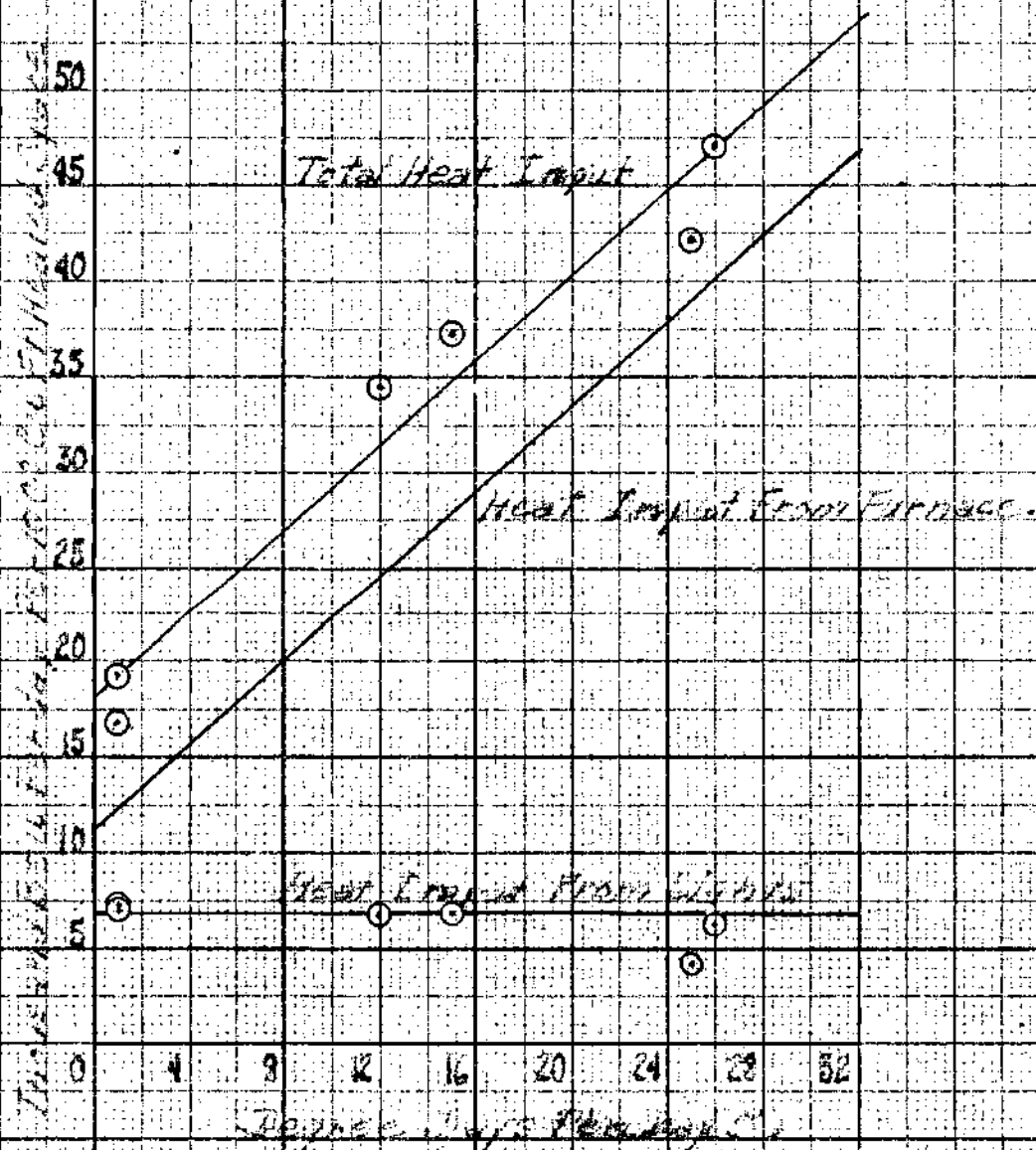
OUTSIDE WALL SURFACE
TEMPERATURE VARIATION
NEAR PANEL EDGE EFFECT
East Atlanta Branch Library
February 2, 1950
Outside Ambient Temperature 41°F

Figure 19



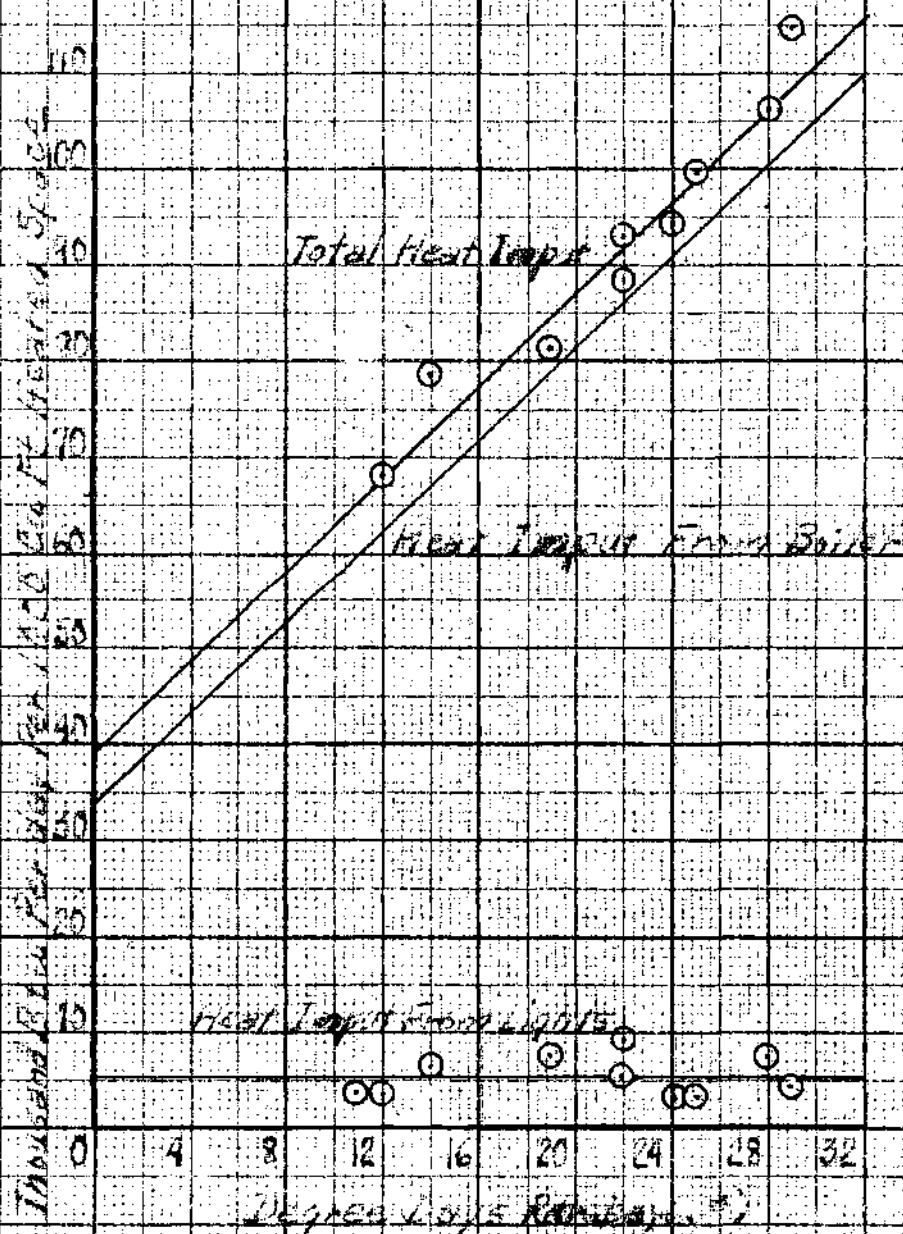
VARIATION OF HEAT INPUT
WITH DEGREE DAYS
East Atlanta Branch, Georgia
Panel Heating

Figure 20



VARIATION OF HEAT INPUT
 WITH DEGREE DAYS
 SINGLE ROOMS EXPOSED TO LIGHT
 Fan and Furnace Heating

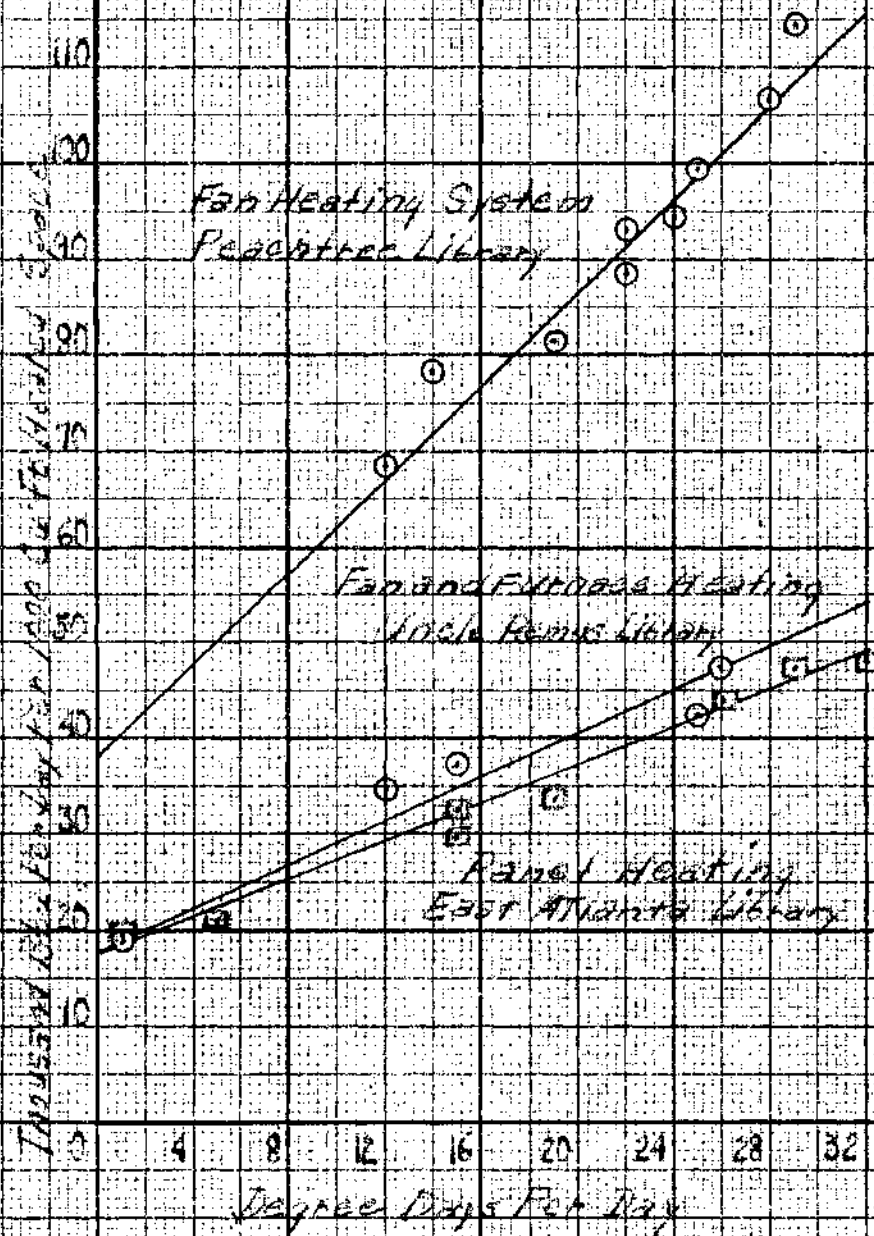
Figure 21



VARIATION OF HEAT INPUT
WITH DEGREE DAYS
FACTORY BUILT LIGHT
EAD Heating System

FIGURE 22

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VARIATION OF HEAT INPUT
WITH DEGREE DAYS

Figure 23